

Competitive Academic Agreement Program



*Corrosion Under Insulation (CUI):
Innovative Solutions to Cold Climate Corrosion Challenges*

Dr. Matt Cullin

1/25/2018



Background

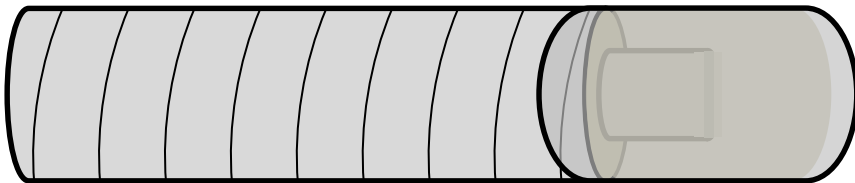


Corrosion Under Insulation (CUI)

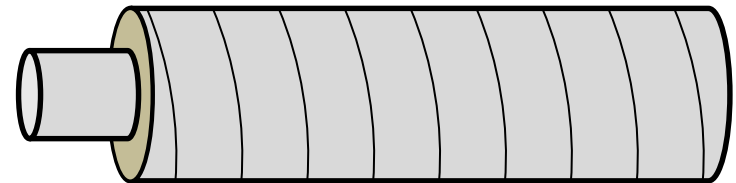
Moisture ingress makes corrosion possible

Interface of field-applied and shop-applied polyurethane (PU) foam is a weak point

Field-applied
insulation

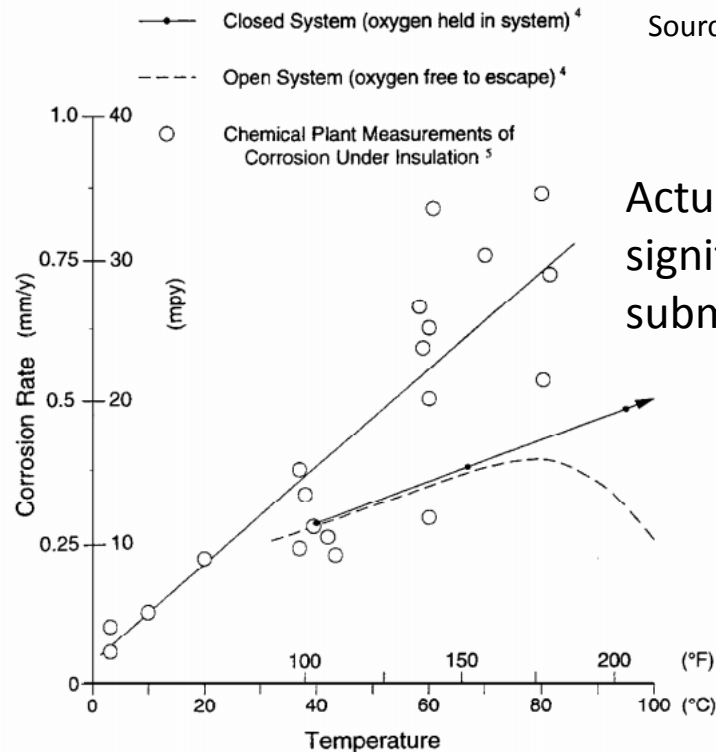


weld pack



Background

General corrosion rate vs. temperature:



Source: NACE RP0198-2004

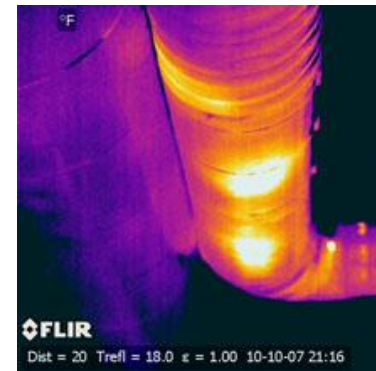
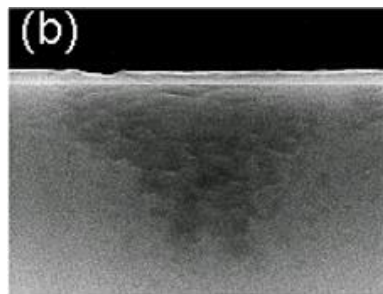
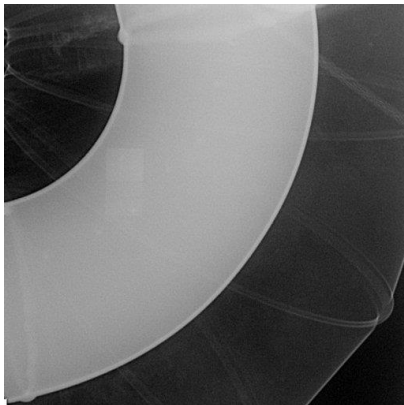
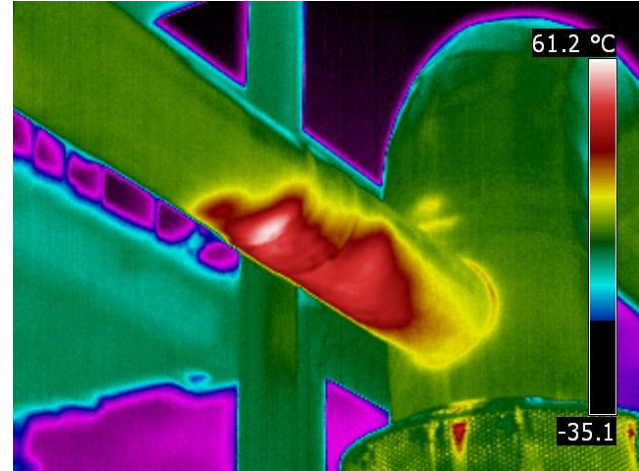
Actual operating conditions produce significantly higher corrosion rates than submersion (lab) tests/models predict

FIGURE 1:
Effect of Temperature on Steel Corrosion in Water



Background

Inspection Techniques:



Background

Injectable corrosion inhibitors:

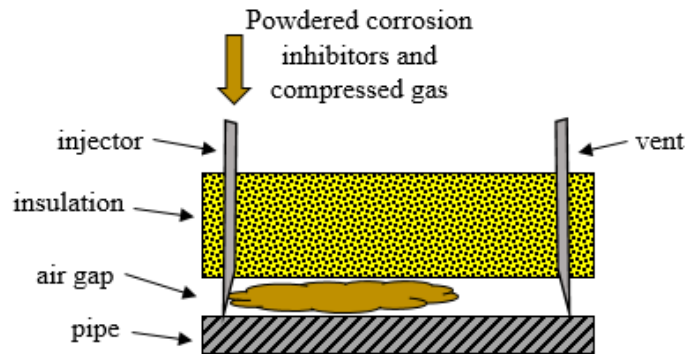
Sodium Bentonite clay

- Cheap
- “Green”
- Readily available
- Swelling characteristics
- Existing research (drilling mud, nuclear casks)

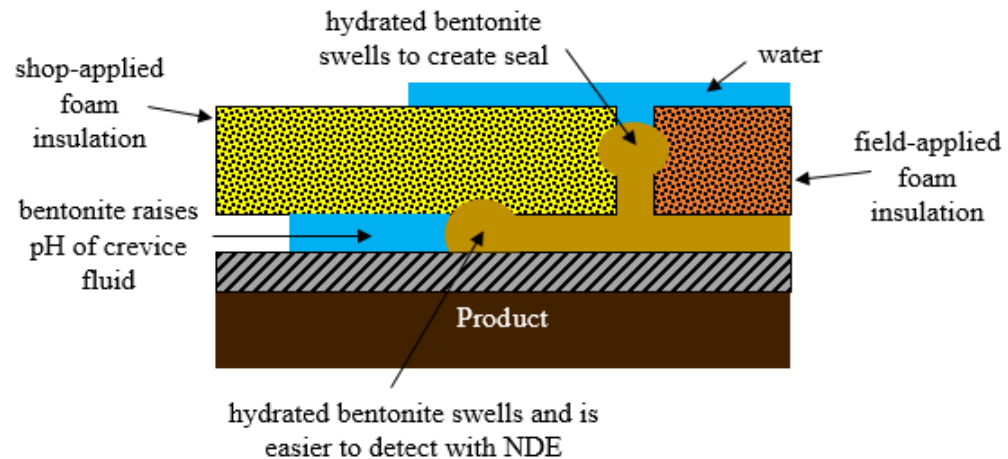


Background

Injector concept:



Longitudinal section view of insulated pipe (not to scale)



Main Objective

To investigate injectable bentonite inhibitors for the mitigation of Corrosion Under Insulation (CUI).



Project Team & Other Sponsors

- Dr. Matthew Cullin (PI)
- 1 Graduate student(M.S.)
- 9 Undergraduate students



UAA College of Engineering
UNIVERSITY *of* ALASKA ANCHORAGE



Summary

- I. Injection apparatus development
 - A. Identification of carrier liquid
 - B. Injector apparatus design
 - C. Injector prototype and testing
- II. Bentonite corrosion testing
 - A. 1L cell
 - B. Foam crevice cell



I-A: Identification of carrier liquid

- Bentonite suspension capacity

Carrier fluid	Suspension concentration (g/mL)
Propylene glycol	0.07
Ethanol	Below measurement limit
Isopropyl alcohol	0.02
Acetone	Below measurement limit
Water	0.03



I-A: Identification of carrier liquid

- Chemical compatibility

Carrier fluid	$\frac{\Delta mass}{\Delta t} \left(\frac{\%}{hr} \right)$	$\frac{\Delta volume}{\Delta t} \left(\frac{\%}{hr} \right)$
Propylene glycol	+ 3.91	- 0.05
Ethanol	+ 4.20	- 0.20
Isopropyl alcohol	+ 3.35	- 0.30
Acetone	+ 8.12	+ 0.77
Water	+ 1.87	- 0.03

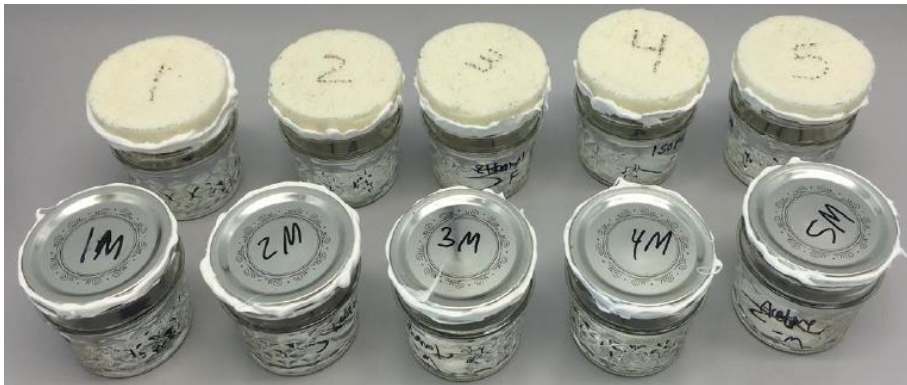


I-A: Identification of carrier liquid

- Adjusted Vapor Transmission Rate (AVTR)

$$AVTR = \frac{y_f - y_m}{A t}$$

Carrier fluid	AVTR $\left(\frac{mg}{cm^2 hr}\right)$
Propylene glycol	Below measurement limit
Ethanol	0.80
Isopropyl alcohol	1.90
Acetone	4.15
Water	0.273



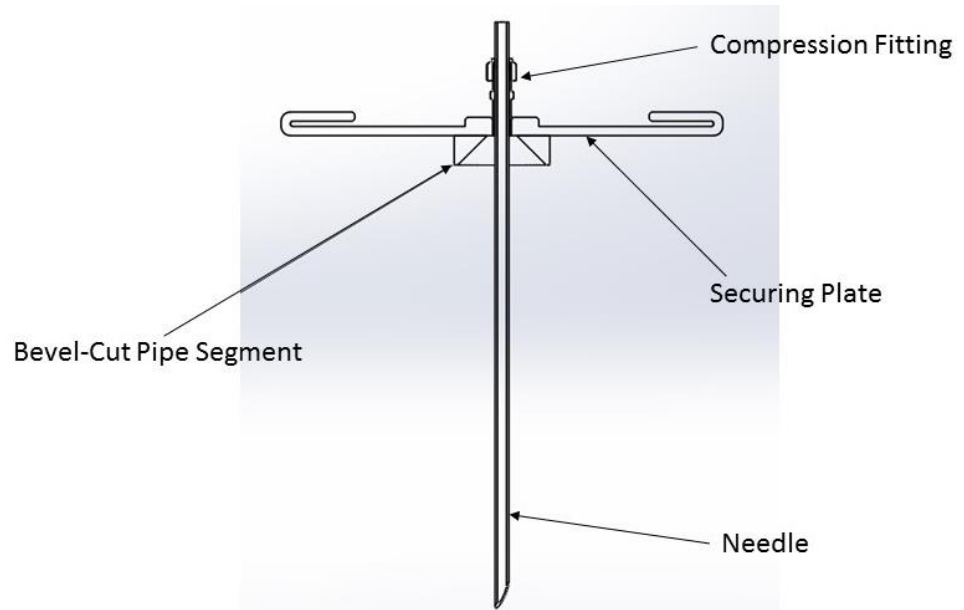
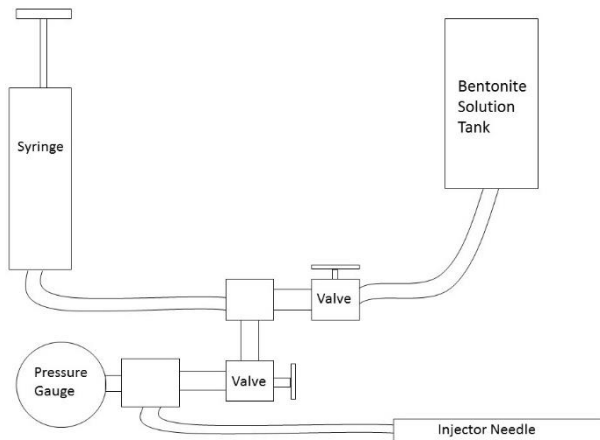
I-B: Injector Apparatus Design

- Design #1



I-B: Injector Apparatus Design

- Design #2



I-C: Injector Prototype and Testing

- Design #2



I-C: Injector Prototype and Testing

- Design #2



I-C: Injector Prototype and Testing

- Design #2



II: Bentonite corrosion testing

Cells: 1L cell and Foam crevice cell

Solutions: Synthetic seawater and foam slurry

Temperatures: 140F, 160F, and 180F

Goals: Determine corrosion rate, inhibitor efficiency, and likelihood of localized corrosion.



II: Bentonite corrosion testing

- Measurement techniques

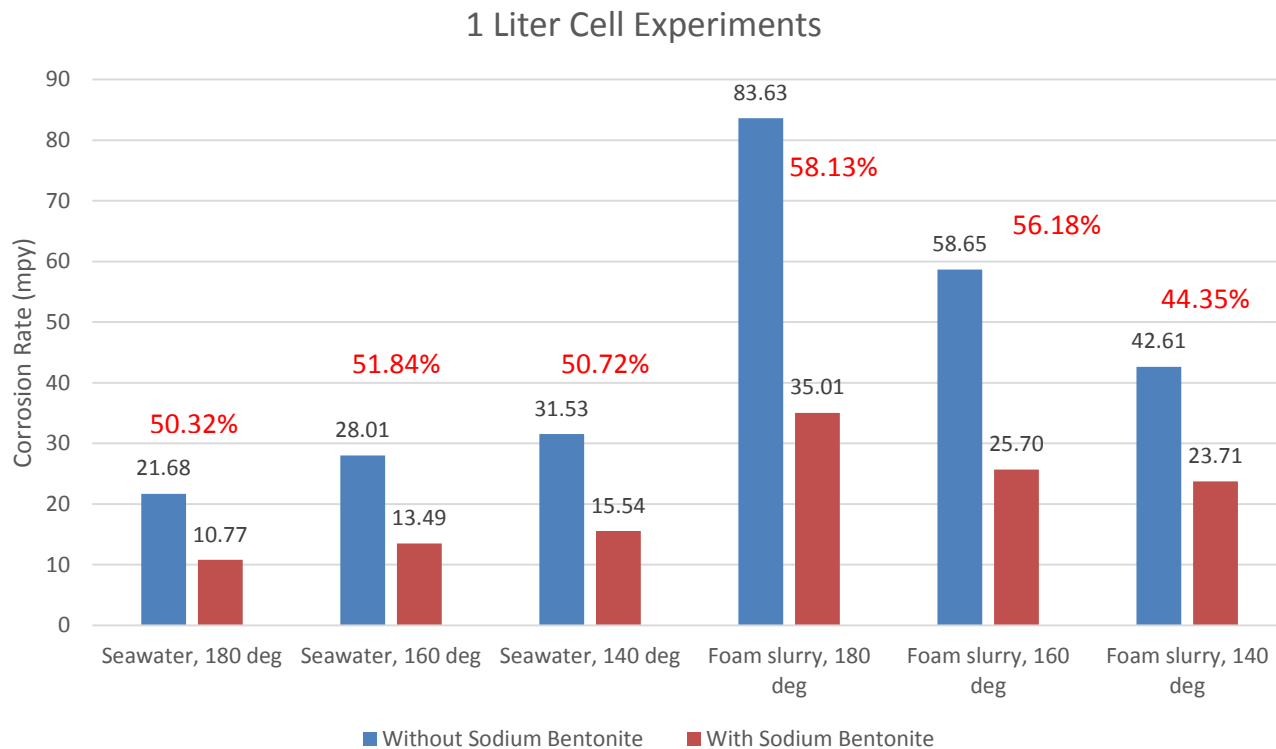


II-A: 1L cell

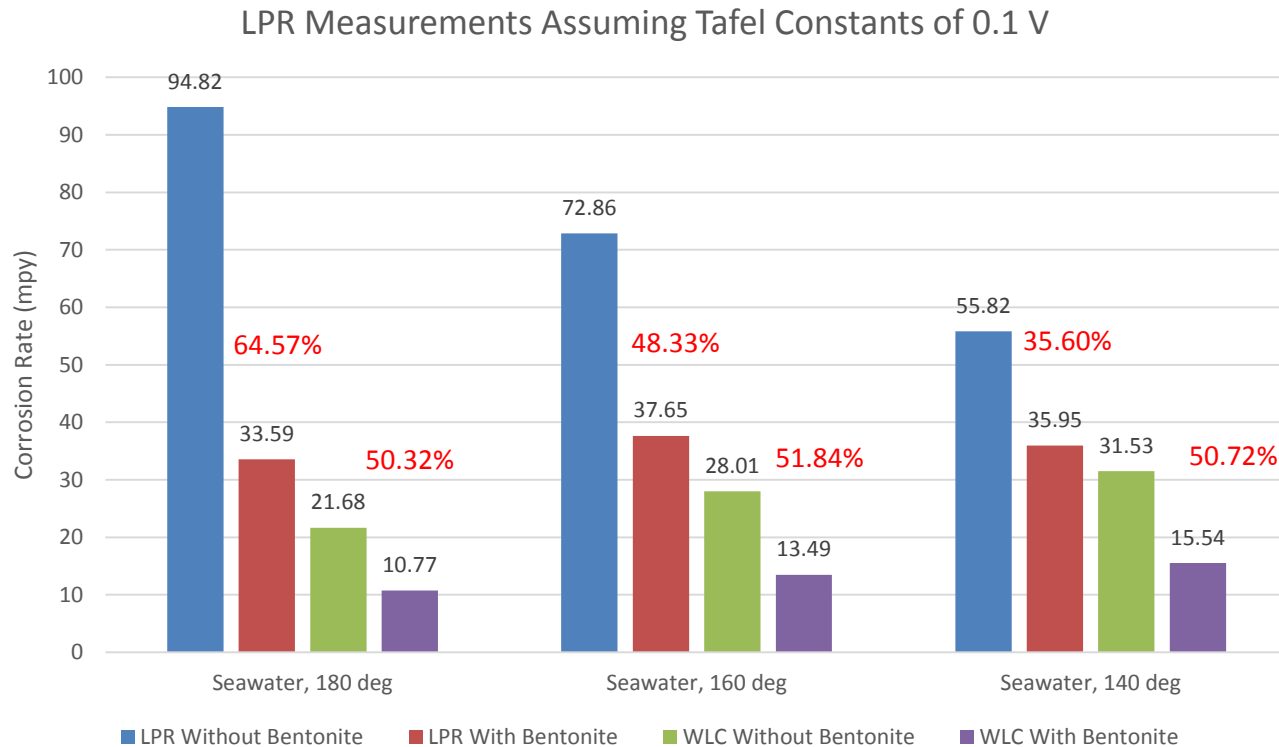
- Apparatus



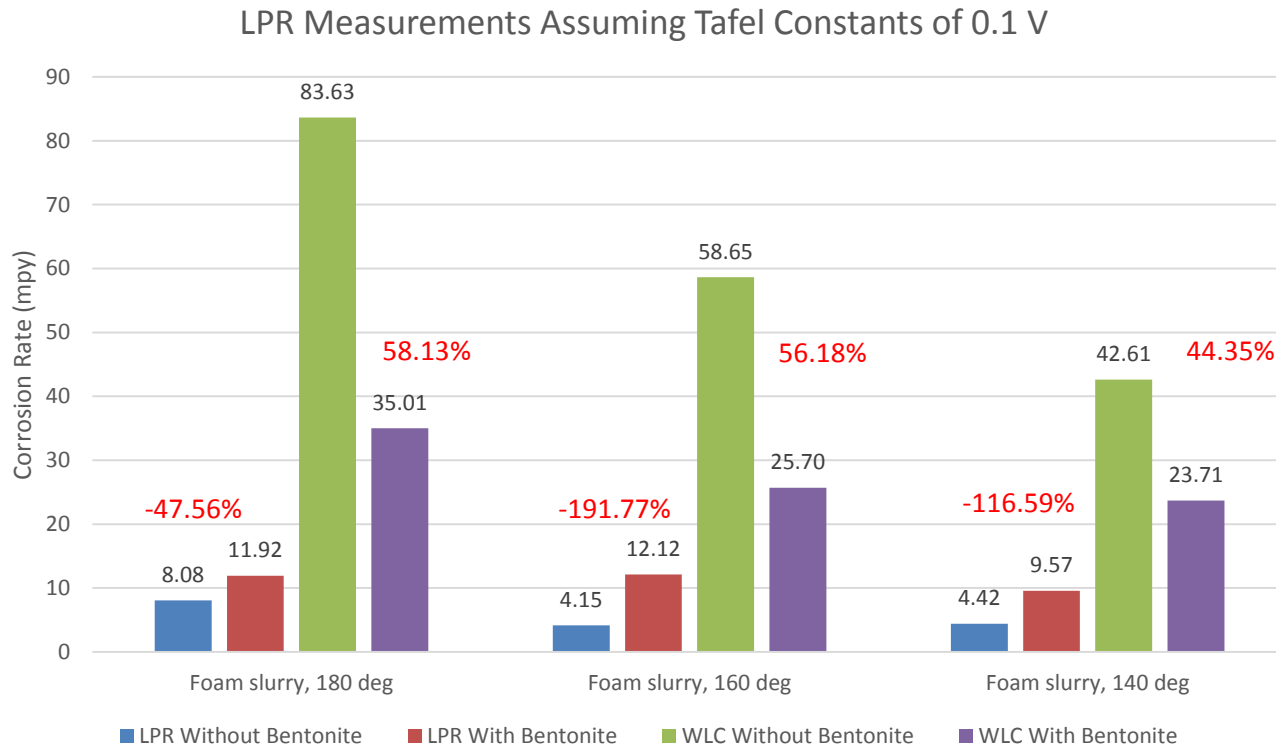
II-A: 1L cell



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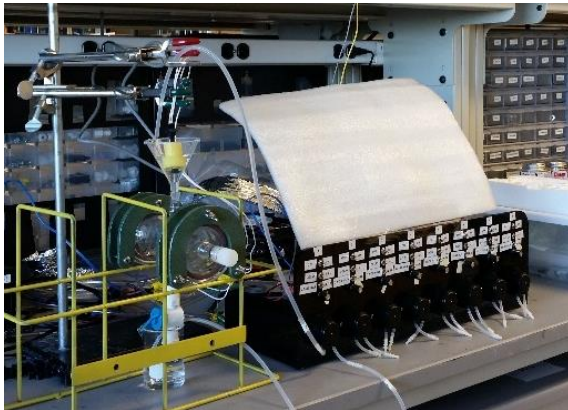
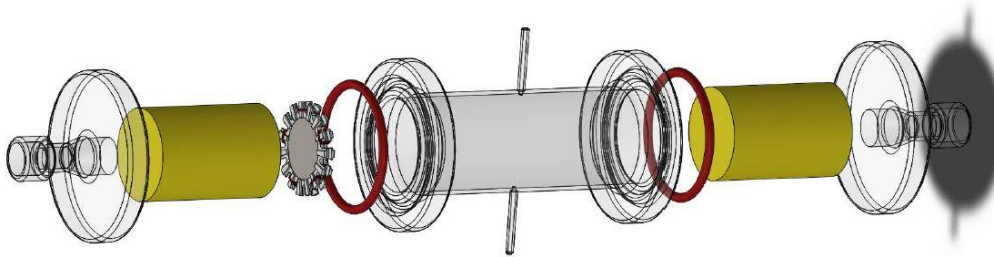


II-A: 1L cell

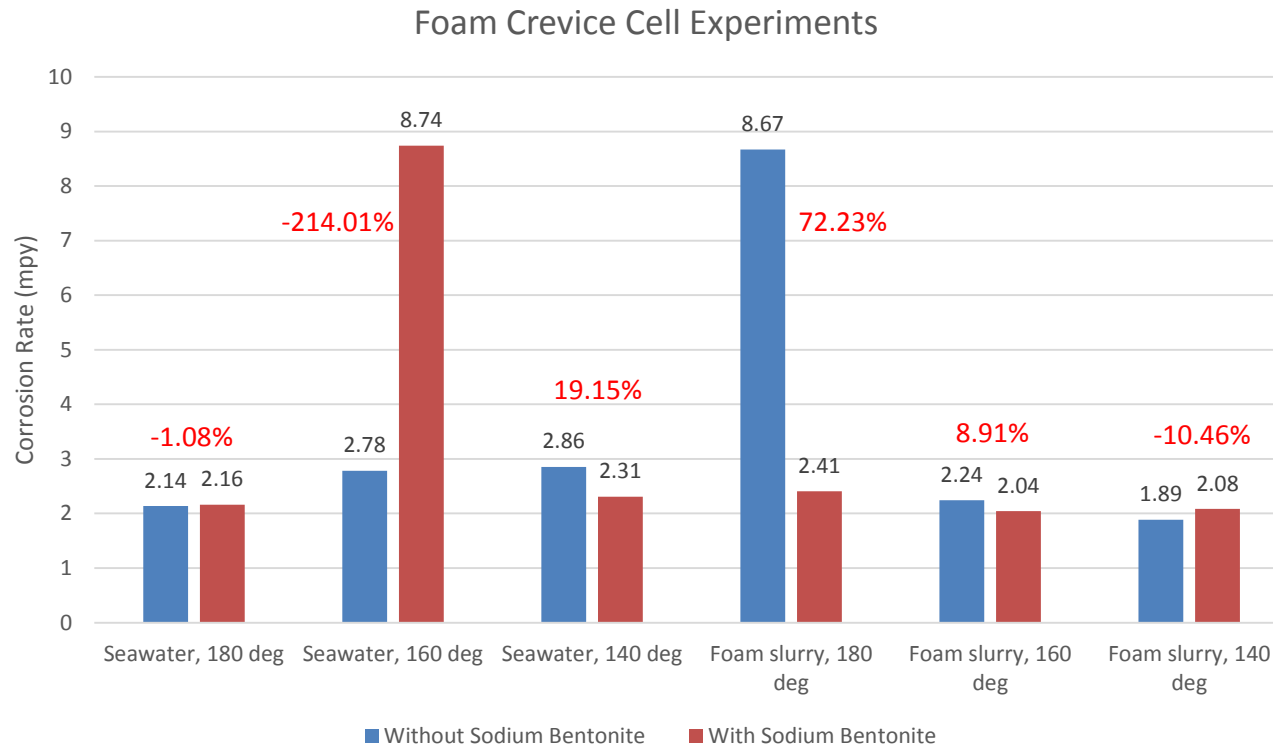


II-B: Foam crevice cell

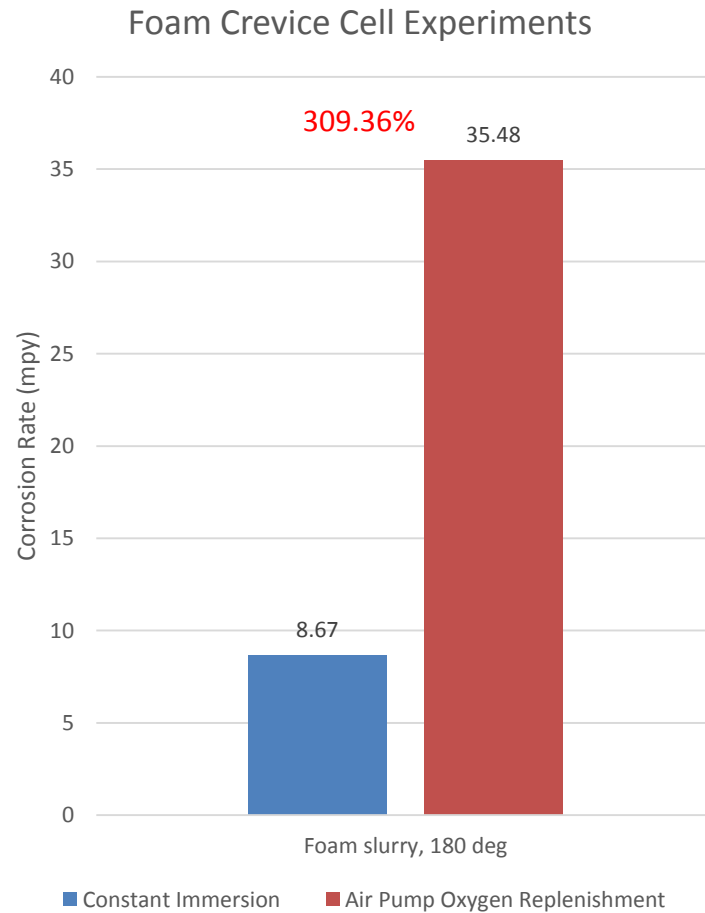
- Apparatus



II-B: Foam crevice cell



II-B: Foam crevice cell



Injector Conclusions

- Injection of a liquid at the pipe-insulation interface is possible
- Injection pressures must be carefully controlled to avoid fracturing the foam insulation
- Radial fracture of the foam insulation tested occurred consistently at injection pressures above 60 psi.
- Liquid injection at the pipe-insulation interface required sustained injection pressures. 200 *mL* of solution required approximately 15-25 minutes to inject fully at the interface. Sustained pressures are easily attained using a dead weight load on a loading arm.
- Injection proceeded even in samples where foam insulation appeared to be tightly adhered to the pipe surface (i.e., no apparent macroscopic flow channel).



Bentonite corrosion testing conclusions

- 50% reduction in corrosion rate observed in bentonite inhibited solutions (synthetic seawater and foam slurry).
- No localized corrosion observed in inhibited solutions.
- Additional work required to make crevice cell conditions sufficiently aggressive.
- Loss of ions and suspended solids from cells apparent. R.O. water replenishment likely inappropriate for future long-term tests.



Future Work

- Refine foam crevice cell operation to obtain a more aggressive environment.
- Perform full scale and/or field tests to confirm bentonite inhibitor performance.
- Test other inhibitor formulations.



Project Reporting

- Final Reporting and any student poster papers are available from:

<https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=570>



THANK YOU!

